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Micro-Positron Emission Tomography for measuring sub-core scale permeability and relative permeability

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Proper descriptions of heterogeneity are essential for understanding and modeling single phase (e.g. contaminant transport, saltwater intrusion) and multiphase (e.g. geologic carbon storage, enhanced oil recovery) transport problems from the sub-core scale to reservoir scale. Application of medical imaging to experimentally quantify these processes has led to significant progress in measurement and understanding of material and fluid transport behavior across laboratory scales. While widely utilized in cancer diagnosis and management, cardiology, and neurology, Positron Emission Tomography (PET) has had relatively limited applications in earth science. This study utilizes a small-bore micro-PET scanner to image and quantify the transport behavior of pulses of a conservative aqueous radiotracer injected during single and multiphase flow experiments in two heterogenous Berea sandstone cores. The cores are discretized into axial-parallel streamtubes, and using the reconstructed micro-PET data, expressions are derived from spatial moment analysis for calculating sub-core tracer flux and pore water velocity. Using the flux and velocity measurements, it is then possible to calculate porosity and saturation from volumetric flux balance, and calculate permeability and water relative permeability from Darcy's law. A numerical simulation model is developed to verify the assumptions of the streamtube dimension reduction technique. A variation of the reactor ratio is presented as an analytical metric to quickly determine the validity of the streamtube approximation in core and column-scale experiments. This study introduces an entirely new method for sub-core permeability and relative permeability quantification, and provides a foundation for future work on experimental measurements of differences in transport behavior across scales.

References

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